STUDIES ON NUTRIENT ABSORPTION OF RICE PLANTS IN TAIWAN (PART 2)
Nutrient Absorption by Japonica and Indica Varieties of Rice in Relation to Temperature

by

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In our previous study[1] we pointed out that high temperatures increased nutrient absorption and plant weights, but it didn't always result in an increase of grain yield. The plants under high temperatures might tend to reinforce vegetative growth at the cost of reducing seed production. It may however be infered that this tendency differ among varieties.

The two variety groups, Japonica and Indica, are both grown in Taiwan while they differ in fertilizer response and its relation to yield. Oka[2] showed that temperature responses could be apportioned into two components, i. e. the rate of growth acceleration due to a rise of temperature and the rate of hastening of flower initiation due to a rise of temperature. The former was generally high in the Indica varieties, while the latter in the Japonica varieties. Oka[3] also pointed out that the fertilizer response was lowered under high temperatures. Indica varieties were found to have a lower fertilizer response and a higher rate of lowering of feritlizer response under high temperatures than Japonica varieties.

The aim of this study is to examine under different temperatures how the two variety groups ditter in the paffern of nutrient absorption and in several agronomic characters.

MATERIALS AND METHODS

A Japonica variety, Taichung no. 65 and an Indica variety, Peh-mi-fen were taken for comparison. The seeds of the genetic stocks preserved in the Institule were used. In the same manner as in 1959, They were grown in two glass-houses keeping different temperatures. Growing status and nutrient absorption were investigated as described in the first report for 1959.

Growth analysis at successive growing stages of the plants were also conducted to know how the two varieties differ in specific growing characters such as relative growth rate, net assimilation rate and leaf area ratio. This is based on the view emphasized by Tsunoda[4] that growing characters of varieties of the same or different crop plants can be comparatively estimated by the growth analysis method. Following this method the dry weight and alive leaf area of plants at successive growing stages are measured and the above-given scores are computed from the data by a certain formula. In this experiment leaf area was measured by printing the shade of alive leaves on

sensitized paper, then cutting the unexposed parts out, the weight of paper was measured to find the leaf area.

RESULTS AND OBSERVATIONS

1. Data for glass-house temperature and measurements of plant characters

The maximum and minimum room temperatures in the two glass-houses were recorded every day. Their average are shown in Table 1 and Fig. 1.

Table 1. Average temperatures

	1st crop, 1960 (Feb. 24–July 12)			2nd crop, 1960 (July 30–Dec. 5)		
	Max.	Min.	Mean	Max.	Min.	Mean
High-temp. glass-house	33.5°C	19.6°C	26.6°C	34.7°C	21.2°C	27.9°C
Low-temp. glass-house	29.7°C	18.6°C	24.2°C	31.0°C	20.0°C	25.5°C
Difference	3.8°C	1.0°C	2.4°C	3.7°C	1.2°C	2.4°C

Culm length, tiller number, plant weight, heading date and other characters were measured at successive growing stages. The results are shown in Table 2 and 3 and Fig. 2.

Table 2. Measurements at maturity

		Taichung no. 65 (Japonica)		Peh-mi-fen (Indica)	
		High-temp. plot	Low-temp. plot	High-temp. plot	Low-temp. plot
1st crop	Culm length (cm)	128.6	120.6	153.6	146.0
	Tiller number	22.0	27.4	24.8	26.6
	Plant weight (g/pot)	105.2	102.3	102.9	97.2
	Grain yield (g/pot)	39.6	40.9	45.6	39.8
	Straw yield (g/pot)	65.6	61.4	57.6	57.4
	Grain/straw ratio	60/100	67/100	79/100	69/100
2nd crop	Culm length (cm)	123.5	124.3	168.3	162.5
	Tiller unmber	21.5	17.9	22.0	21.7
	plant weight (g/pot)	82.9	79.9	102.7	99.3
	Grain yield (g/pot)	36.9	33.5	44.1	40.9
	Straw yield (g/pot)	46.0	46.4	58.6	58.4
	Grain/straw ratio	80/100	72/100	75/100	70/100

Elongation of plant was apparently promoted by the high temperatures, so that the dry matter weight of plants in the high temperature plot was always larger than that in the low temperature plot. This trend was more significant in the first crop than in the second crop.

In the first crop the high temperatures reduced grain yield and grain/straw ratio of Ponlai rice, Taichung no. 65, in the same manner as in 1959. In the second crop such a tendency was not found, however. This might be because of too low temperatures

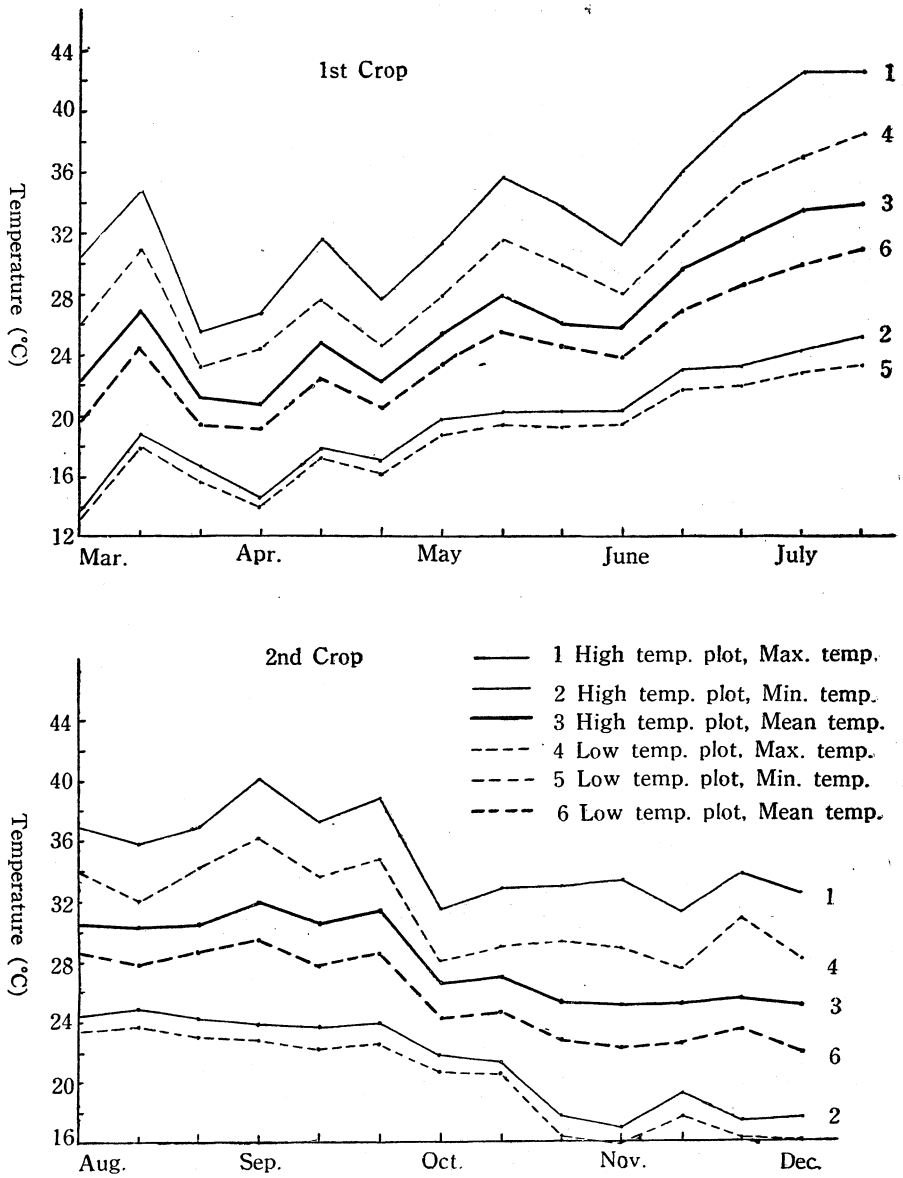

Fig. 1. Change of temperatures in the two glass-houses

after heading of the crop season. It seemed that temperature after heading play an important role in the determing grain yield.

In the native variety, Peh-mi-fen, high temperatures tended to promote grain yield in both the first and second crops. This variety may be more adaptive to high temperature than Taichung no. 65.

Plants in the high temperature plot generally headed earlier than those in the low temperature plot the first crop, but in at the same time in the second crop. The

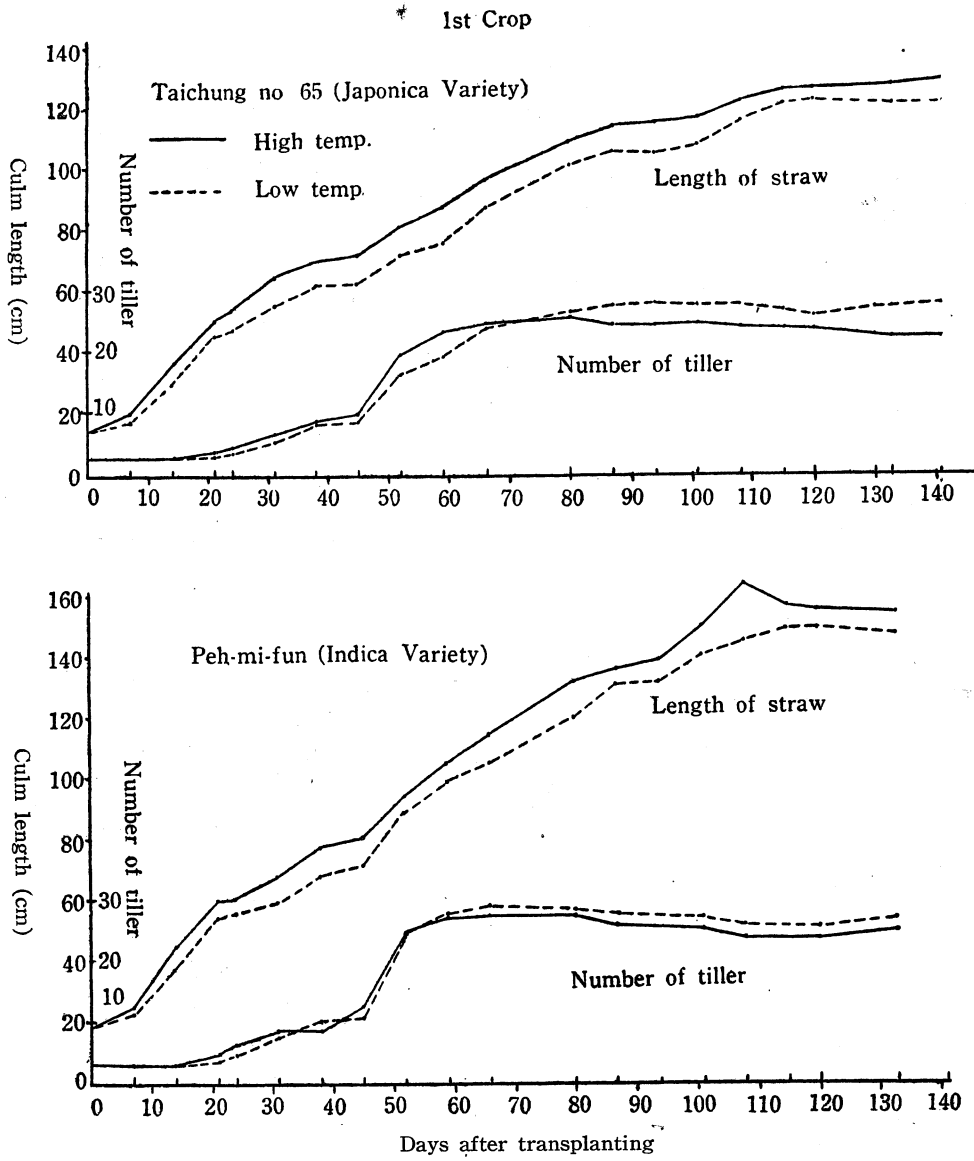

Fig. 2a. Growth status of the plants, 1st crop, 1960

Table 3. Heading date

		1st crop, 1960	2nd crop, 1960
		Heading date	Heading date
Taichung no. 65	High temp. plot	June 8-16	Oct. 17-22
	Low temp. plot	June 16-25	Oct. 17-22
Peh-mi-fen	High temp. plot	June 2-6	Oct. 15-22
	Low temp. plot	June 5-7	Oct. 15-21

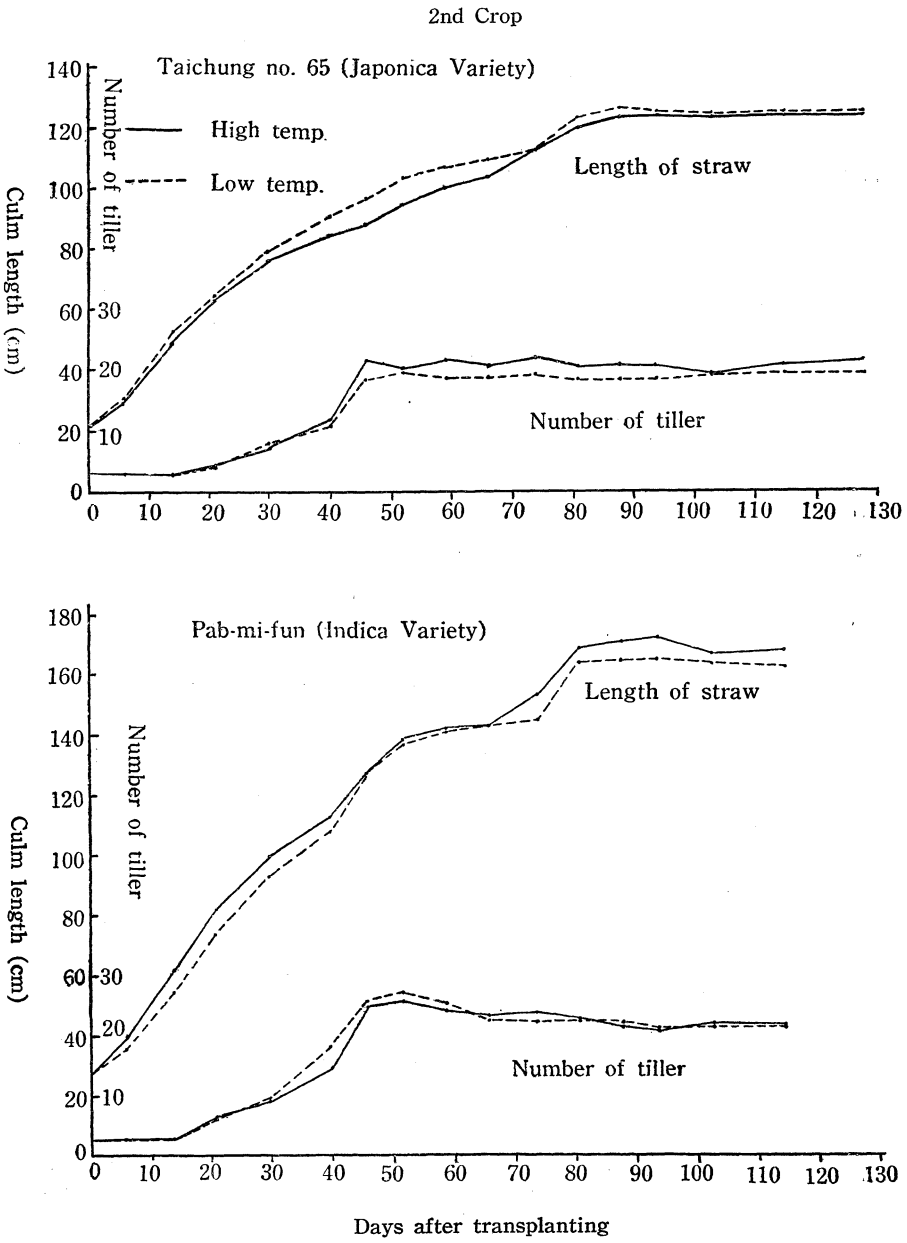

Fig. 2b. Growth status of the plants, 2nd crop, 1960

heading date of Indica variety was generally earlier than that of Japonica variety similarly in the first and second crop.

2. Result of growth analysis

Table 4a. Results of growth analysis at successive growing stages (1st crop, 1960)

Variety	Plot	Date	Days after planting	Dry wt. of plant (g/pot)	Leaf Area dm^2/pot	RGR (%) Relative Growth Rate	NAR ($mg/dm^2/day$) Not Assimilation Rate	LAR (dm^2/g) Leaf Area Ratio
Japonica	Hightem	Mar. 31	38	1.81	4.08			2.25
		Apr. 14	52	5.25	9.24	7.60*	38.9**	1.76***
		Apr. 28	66	12.70	23.58	6.30	34.7	1.86
		May 12	80	26.35	41.52	5.21	30.7	1.58
		June 2	101	48.4	44.77	2.89	24.4	0.93
		June 21	120	78.8	20.74	2.56	51.2	0.26
		July 12	141	105.2	25.79	1.37	54.1	0.24
	Lowtemp.	Mar. 31	38	1.17	2.79			2.38
		Apr. 14	52	4.48	8.04	9.58	47.6	1.79
		Apr. 28	66	9.81	21.19	5.59	28.0	2.16
		May 12	80	19.23	29.59	4.80	26.7	1.54
		June 2	101	46.2	47.99	4.17	33.7	1.04
		June 21	120	74.3	40.48	2.50	33.4	0.55
		July 12	141	102.3	30.97	1.57	37.5	0.30
Indica	Hightemp.	Mar. 31	38	3.34	7.57			2.27
		Apr. 14	52	9.25	18.83	7.27	34.1	2.04
		Apr. 28	66	19.99	41.93	5.50	26.6	2.10
		May 12	80	40.37	58.75	5.01	29.2	1.46
		June 2	101	76.7	35.37	3.05	37.7	0.46
		June 21	120	101.8	14.74	1.49	55.8	0.14
		July 4	133	102.9	8.37	0.08	7.5	0.08
	Lowtemp.	Mar. 31	36	1.99	3.76			1.89
		Apr. 14	52	8.19	15.32	10.93	53.8	1.55
		Apr. 28	66	17.30	37-92	5.33	26.1	2.19
		May 12	80	34.38	48.44	4.90	28.4	1.41
		June 2	101	56.2	37.79	2.34	24.2	0.67
		June 21	120	93.4	10.81	2.67	90.7	0.12
		July 4	133	97.2	10.45	0.31	27.4	0.11

Example of calculation

* RGA(%)=(loge 5.25g−loge 1.81g)/52day−38 day=0.076 or 7.6%

** NAR=(5.250mg−1.180mg)(loge 9.24dm^2−loge 5.25dm^2)/(52 day−38 day)(9.24 dm^2−5.25dm^2) =38.9 $mg/dm^2/day$

*** LAR=9.24dm^2/5.25g=1.76dm^2/g

Table 4b. Results of growth analysis at successive growing stages (2nd crop, 1960)

Variety	Plot	Date	Days after planting	Dry wt. of plant (g/pot)	Leaf Area dm^2/pot	RGR (%) Relative Growth Rate	NAR ($mg/dm^2/day$) Net Assimilation Rate	LAR (dm^2/g) Leaf Area Ratio
Japonica	Hightemp.	Aug. 29	30	2.110	4.57			2.17
		Sep. 20	52	12.019	20.00	5.42	29.1	1.67
		Oct. 12	74	39.300	44.88	5.89	44.1	1.14
		Nov. 1	94	62.60	30.89	2.32	30.8	0.49
		Dec. 5	128	82.9	0	0.83	66.5	0
	Lowtemp.	Aug. 29	30	2.130	6.83			3.21
		Sep. 20	52	15.616	25.54	6.23	29.7	1.64
		Oct. 12	74	33.975	64.21	3.81	24.4	1.89
		Nov. 1	94	55.9	24.65	2.49	26.5	0.44
		Dec. 5	128	79.8	0	0.87	91.5	0
Indica	Hightemp.	Aug. 29	30	3.796	9.70			2.56
		Sep. 20	52	24.574	42.82	7.48	37.1	1.74
		Oct. 12	74	54.250	47.97	3.61	30.1	0.88
		Nov. 1	94	86.6	22.12	2.35	48.4	0.26
		Nov. 22	115	102.7	0	0.81	106.8	0

		Aug. 29	30	3.959	11.36			2.87
		Sep. 20	52	26.916	54.40	7.66	42.2	2.02
Indica	Lowtemp.	Oct. 12	74	52.725	55.33	3.06	23.2	1.05
		Nov. 1	94	76.8	13.82	1.66	41.3	0.18
		Nov. 22	115	99.3	0	1.25	108.2	0

Area of living leaves and plant weight were measured at the successive growing stages as shown in Table 4 and "Relative Growth Rate, Net Assimilation Rate, and Leaf Area Ratio" were estimated following the procecdures described in Tsunoda's paper[4]. Relative growth rate was high at the early stage, and then decreased gradually till maturity. Net assimlation rate showed two peaks, one peak at the stage before tillering and the other at the ripening stage. It became the lowest about 20 days before heading in the first crop. Leaf area ratio decreased as the plant grew. Although some differences were recognized between varieties and temperature treatments, more intensive studies will beneeded for drawing a conclusion regarding nutrio-physiological differences between varieties.

3. Inorganic nutrient absorption

In the first crop, N and P contents were at the maximum during the seedling stage, and then decreased gradually till harvesting, as shown in Teble 5 and Fig. 3. Since the nursery bed in the first crop were dressed with NPK fertilizers, therfore the values at the transplanting stage might have been higher than in ordinary rice seedlings. Nevertheless potassium concentration were still increased after transplanting and reached the maximum at about 40 days after transplanting. It seemed that plants absorbed potassium more rapidly than absorbing other elements at the early stage. In the second crop, N and K contents reached the maximum at about 30 days after transplanting. P contents was the maximum at transplating. Differences of nutrient contents between temperature treatments as well as bbtween varieties were not significant.

The amounts of nutrients absorbed by the plants in the high temperature plot were generally larger than that in the low temperature plot, as shown in Table 6 and Fig. 4. In the Indica variety the increase of nutrient absorption under high temperatures

Table 5a. Inorganic nutrient content (% on oven bry basis) 1st crop, 1960

Variety	Date	High temp. plot			Low temp. plot		
		N%	P_2O_5%	K_2O%	N%	P_2O_5%	K_2O%
Japonica. Taichung no. 65	Feb. 22 (planting)	4.628	2.280	4.464	4.628	2.280	4.464
	Mar. 17	4.324	1.055	5.904	4.660	1.297	5.930
	Mar. 31	4.280	1.075	6.048	4.420	1.010	5.520
	Apr. 14	3.898	1.048	5.222	3.892	1.062	5.356
	Apr. 28	3.803	1.196	5.254	4.278	1.119	4.835
	May 12	2.579	0.866	3.233	3.101	0.862	3.334
	June 2	1.592	0.643	2.155	1.604	0.758	1.818
	June 21	1.207	0.494	1.445	1.251	0.570	1.395
	July 12 (harvesting)	1.086	0.427	1.223	1.039	0.454	1.187

	Grain	1.341	0.610	0.592	1.371	0.581	0.594
	Stem & Sheath	0.630	0.330	1.368	0.609	0.396	1.440
	Leaf Blade	1.564	0.288	2.202	1.338	0.311	1.902
Indica, Peh-mi-fen	Feb. 22 (planting)	4.639	2.160	4.128	4.639	2.160	4.128
	Mar. 17	4.346	1.102	5.856	4.476	1.155	6.144
	Mar. 32	4.492	1.085	6.000	4.422	1.165	6.384
	Apr. 14	3.574	0·950	5.201	3.798	0.999	5.821
	Apr. 28	3·482	0.994	4.239	3.724	0.988	4.630
	May 12	2.448	0.752	2.673	2.254	0.808	2.656
	June 2	1.381	0.485	1.722	1.528	0.650	2.098
	June 21	1.144	0.471	1.370	1.115	0.452	1.314
	July 4 (harvesting)	1.152	0.479	1.302	1.112	0.450	1.269
	Grain	1.591	0.790	0.560	1.532	0.798	0.568
	Stem & Sheath	0.621	0.253	2.060	0.585	0.207	1.886
	Leaf Blade	1.151	0.192	1.572	1.362	0.211	1.401

Table 5b. Inorganic nutrient content (% on oven dry basis) 2nd crop, 1960

Variety	Date	High temp. plot			Low temp. plot		
		N%	P_2O_5%	K_2O%	N%	P_2O_5%	K_2O%
Japonica, Taichung no. 65	July 30 (planting)	3.00	0.846	3.36	3.00	0.846	3.360
	Aug. 29	3.576	0.814	4.903	3.127	0.785	5.238
	Sep. 20	3.146	0.650	3.855	3.121	0.651	3.926
	Oct. 12	2.324	0.739	2.836	2.254	0.712	2.920
	Nov. 1	1.674	0.651	2.072	1.623	0.569	2.030
	Dec. 5 (harvesting)	1.581	0.580	1.730	1.414	0.531	1.707
	Grain	1.69	0.740	0.552	1.65	0.708	0.588
	Stem & Sheath	1.26	0.495	2.808	1.01	0.448	2.628
	Leaf Balde	2.08	0.345	1.730	1.80	0.299	2.244
Indica, Peh-mi-fen	July 30 (planting)	3.31	0.958	3.984	3.31	0.958	3.984
	Aug. 29	3.995	0.659	5.771	3.734	0.471	5.279
	Sep. 20	3.128	0·593	3.715	2.891	0.858	3.142
	Oct. 12	1.672	0.506	2.391	1.591	0.575	2.008
	Nov. 1	1.196	0.484	1.654	1.145	0.543	1.676
	Nov. 22 (harvesting)	1.107	0.411	1 412	0.974	0.425	1.298
	Grain	1.47	0.602	0.576	1.37	0.658	0.600
	Stem & Shoath	0.70	0.279	2.352	0.58	0.270	1.992
	Leaf Blade	1.13	0.244	1.356	0.96	0.243	1.272

Table 6a. Distribution of inorganic nutrients in plants at maturity, 1st crop, 1960

Variety	Plot	Part	N	P_2O_5	K_2O
			mg/pot (Index)	mg/pot (Index)	mg/pot (Index)
Japonica, Taichung no. 65	High temp. plot	Grain	531.0 (47)	241.5 (54)	234.4 (18)
		Stem & Sheath	281.0 (25)	147.2 (33)	610.1 (47)
		Leaf Blade	328.4 (29)	60.5 (13)	442.6 (35)
		Total	1,140.4 (100)	449.2 (100)	1,287.1 (100)
		(Index)	(100)	(39)	(113)
	Low temp. plot	Grain	550.5 (52)	237.6 (51)	242.9 (20)
		Stem & Sheath	258.2 (24)	167.9 (36)	610.6 (50)
		Leaf Blade	254.2 (24)	59.1 (13)	331.4 (30)
		Total	1,062.9 (100)	464.6 (100)	1,214.9 (100)
		(Index)	(100)	(44)	(114)

Indica, Peh-mi-fen	High temp. plot	Grain	725.5 (61)	360.2 (73)	255.4 (19)
		Stem & Sheath	234.1 (20)	95.4 (19)	776.6 (5)
		Leaf Blade	225.6 (19)	37.6 (8)	308.1 (23)
		Total	1,185.2 (100)	493.2 (100)	1,340.1 (100)
		(Index)	(100)	(42)	(113)
	Low temp. plot	Grain	609.7 (56)	317.6 (73)	226.1 (18)
		Stem & Sheath	233.4 (22)	82.6 (19)	762.5 (62)
		Leaf Blade	238.4 (22)	36.9 (8)	245.1 (20)
		Total	1,081.5 (100)	137.1 (100)	1,233.7 (100)
		(Index)	(100)	(40)	(114)

Table 6b. Distribution of inoraganic nutrients in plants at maturity, 2nd crop, 1960

Variety	Plot	Part	N	P_2O_5	K_2O
			mg/pot (Index)	mg/pot (Index)	mg/pot (Index)
Japonica, Taichung no. 65	High temp. plot	Grain	632.6 (48)	273.1 (56)	203.7 (14)
		Stem & Sheath	114.2 (32)	162.7 (34)	923.1 (64)
		Leaf Blade	273.0 (21)	45.3 (9)	307.1 (21)
		Totsl	1,310.8 (100)	481.1 (100)	1,433.9 (100)
		(Index)	(100)	(37)	(109)
	Low temp. plot	Grain	552.1 (49)	236.9 (56)	196.7 (14)
		Stem & Sheath	329.5 (29)	146.2 (34)	857.5 (63)
		Leaf Blade	247.7 (22)	41.1 (10)	308.8 (23)
		Total	1,129.3 (100)	424.2 (100)	1,363.0 (100)
		(Index)	(100)	(38)	(121)
Indica, Peh-mi-fen	High temp. plot	Grain	647.5 (57)	265.2 (63)	253.7 (17)
		Stem & Sheath	282.3 (25)	112.5 (27)	948.4 (65)
		Leaf Blade	207.1 (18)	44.7 (10)	248.5 (17)
		Total	1,136.9 (100)	422.4 (100)	1,450.6 (100)
		(Index)	(100)	(37)	(128)
	Low temp. plot	Grain	560.3 (58)	269.1 (64)	253.4 (20)
		Stem & Sheath	234.8 (24)	109.3 (26)	806.3 (63)
		Leaf Blade	171.8 (18)	43.5 (10)	227·7 (18)
		Total	966.9 (100)	421.9 (100)	1,288.4 (100)
		(Index)	(100)	(44)	(133)

appeared to be followed by an increased transmission of nutrients to grains., but in the Japonica variety, the nutrient transmission to grains did not increase especially in the first crop. Japonica rice seemed to be less adaptive regarding grain formation under high temperatures than Indica rice.

SUMMARY

Agronomic characters and nutrient absorption of a Japonica veriety, Taichung no. 65 and an Indica variety, Peh-mi-fen under different temperature conditions were investigated. Pot experiments were made in two glass-houses with different temperatures, one glass-house with closed and the other with opened windows The former had temparatures 2.4° C higher than the latter on the average for the growing period.

High temperatures promoted straw elongation increase of dry matter weights and the heading date in both varieties. This trend was more signigicant in the first crop than in the second crop.

In Taichung no. 65 high temperatures decreased grain yield and grain/straw ratio so

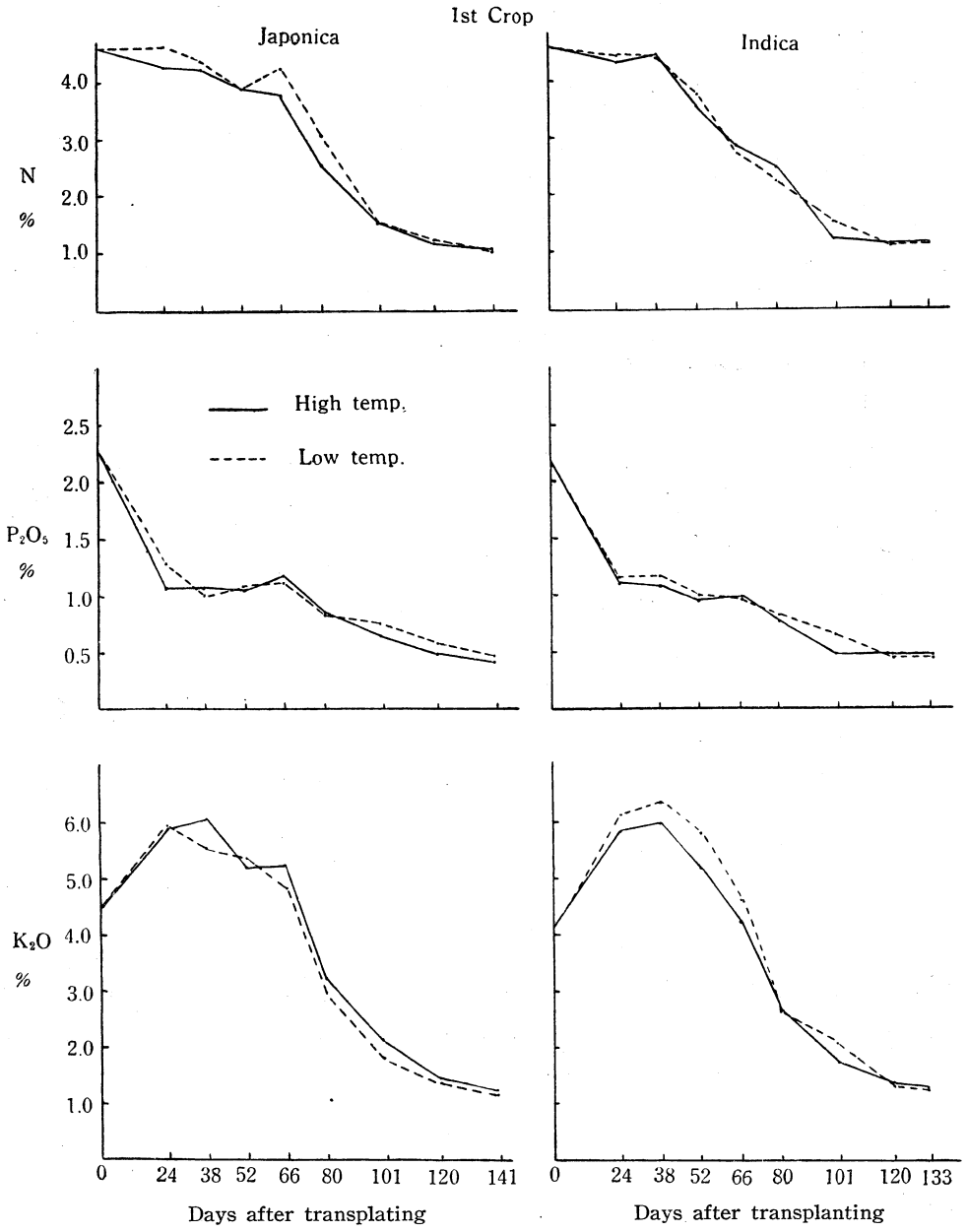

Fig. 3a. Change of nutrient contents in the plants, 1st crop, 1960

far as the first crop is concerned. In Peh-mi-fen, high temperatures tended to increase grain yield and grain/straw ratio.

Differences in nutrient concentrations between temperature treatments and between varieties were not very significant.

High temperatures generally increased nutrient absorption. In the Indica variety

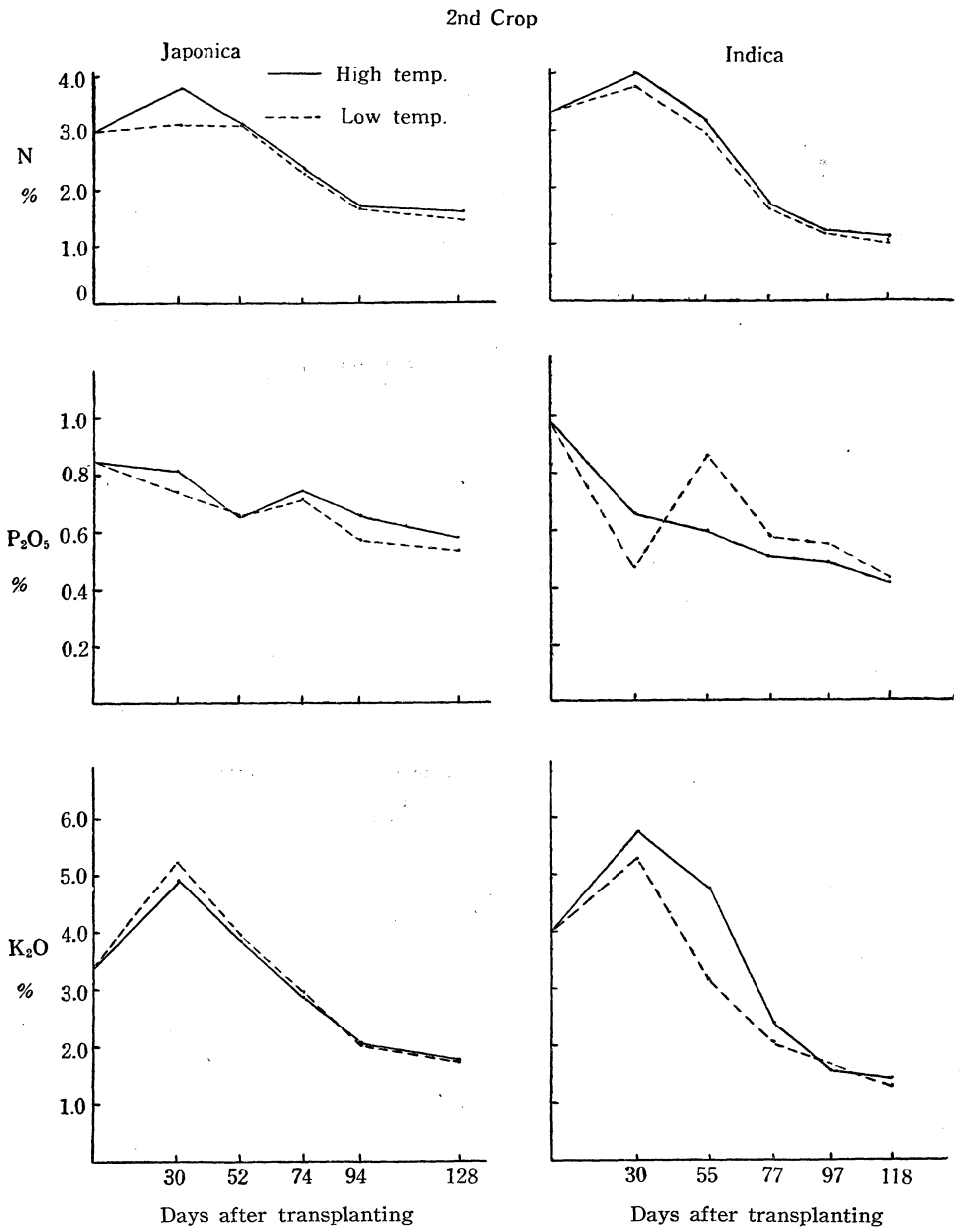

Fig. 3b. Change of nutrient contents in the plants, 2nd crop, 1960

the increasing of nutrient absorption under high temperatures appeared to result in an increased transmission of nutrients to grains. but in the Japonica variety, it didn't always bring abcot an increased nutrient transmission to grains.

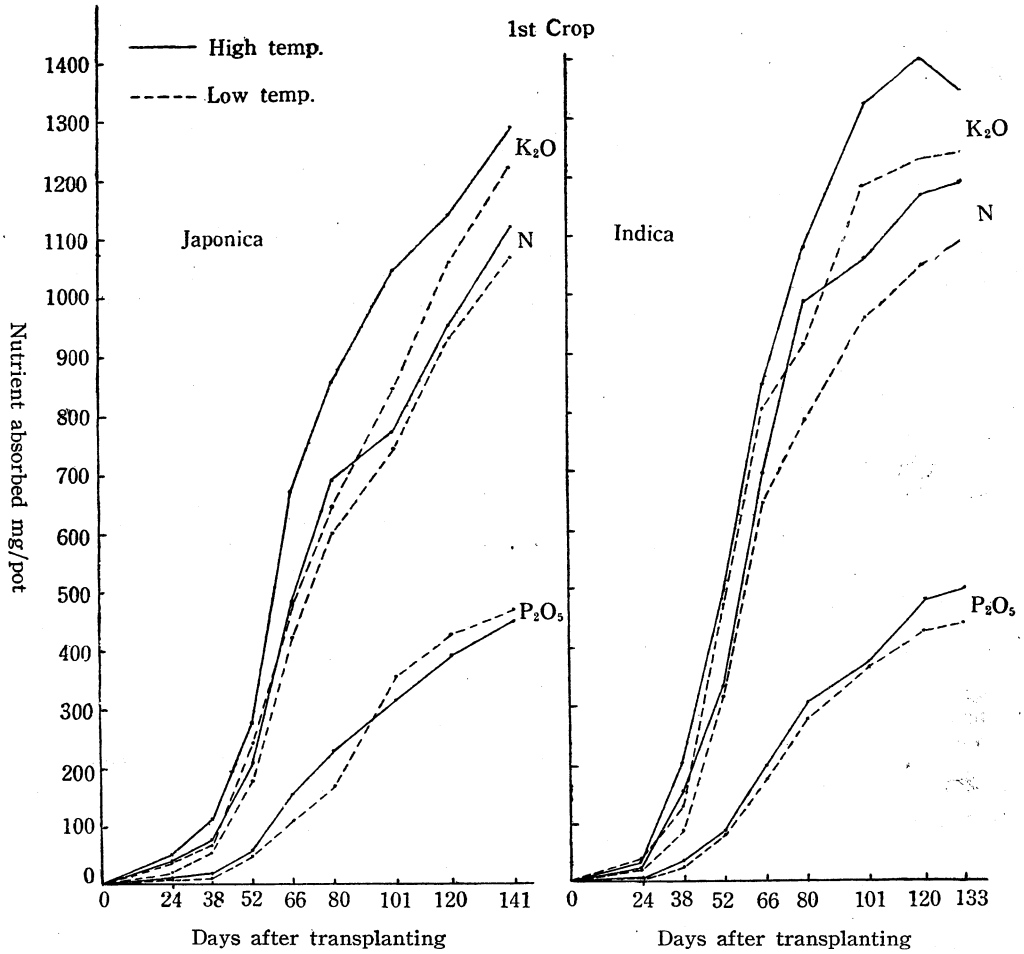

Fig. 4a. Amounts of nutrients absorbed, 1st crop, 1960

LITERLTURE CITED

(1) CHIU, T. F., LIAN, S. and HSU, S, C. (1960): Studies on nutrient absorption by rice plants in Taiwan (Part 1). Agricultural Research Vol. 9. No. 4.

(2) OKA, H. I. (1954): Varietal variation in the responses to day-length and temperature, and the number of days of growing period. Jap. Jour.Breeding, 4(2): 92-100.

(3) OKA, H. I. (1956): Variation in fertilizer response among rice varieties. Jour. Agr. Assoc. of China, New Series No. 13: 35-41

(4) TSUNODA, J. (1953): Specific characters of growth and yield on crops. Agriculture and Horticulture, Japan Vol. 33, No. 11.

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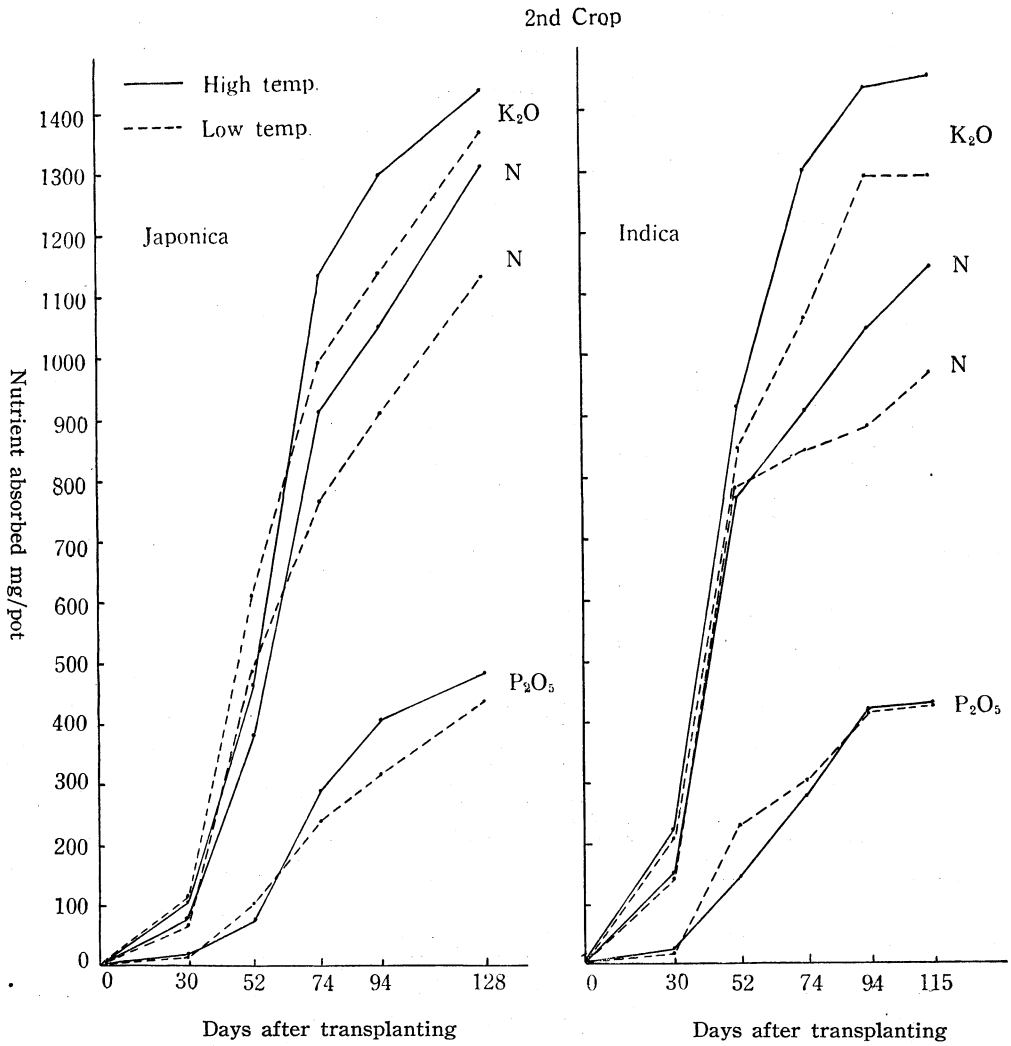

Fig. 4b. Amounts of nutrients absorbed, 2nd crop, 1960

臺灣水稻之養分吸收之研究（第二報）

日本型及印度型水稻之養分吸收與溫度之關係

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摘　　要

繼第一報以蓬萊種水稻，臺中65號觀察溫度對養分吸收之影響後，本年度另增在來種水稻，白米粉一種以比較兩品種水稻在不同溫度處理下之養分吸收狀況和生育性狀，結果如下。試驗仍如前報於兩玻璃室內進行，其一係玻璃窗開啓，另一則關閉以做爲比較上之高低溫區。如此水稻生育期

間，高溫區平均溫度可高於低溫區約 2.4°C。

（1） 水稻收穫時之生育狀態及穀藁收量如下表。

收穫調查結果表

		臺中65號（日本型）		白米粉（印度型）	
		高溫區	低溫區	高溫區	低溫區
第一期作	株高 (cm)	128.6	120.6	153.6	146.0
	分蘖數	22.0	27.4	24.8	26·6
	總收量 (g/pot)	105.2	102.3	102.9	97.2
	穀 (g/pot)	39.6	40.9	45.6	39.8
	藁 (g/pot)	65.6	61.4	57.6	57.4
	穀/藁比	60/100	67/100	79/100	69/100
第二期作	株高 (cm)	123.5	124.3	168.3	162.5
	分蘖數	21.5	17.9	22.0	21.7
	總收量 (g/pot)	82.9	79.9	102.7	99.3
	穀 (g/pot)	36.9	33.5	44.1	40.9
	藁 (g/pot)	46.0	46.4	58.6	58.4
	穀/藁比	80/100	72/100	75/100	70/100

無論是在來種或是蓬萊種，高溫均促進株高，乾物總收量和出穗。此種傾向以第一期作較第二期作明顯。蓬萊種水稻因第一期作之高溫處理而減低穀產量與穀/藁比率，惟第二期作高溫之效果却反而促其提高。至於在來種則無論第一期作或第二期作穀產量與穀/藁比率均以高溫區較高。由此可知日本型和印度型兩品種在溫度之反應上必有差別。

（2） 本次試驗中，水稻生育各階段之三要素濃度並無溫度處理或不同品種間之明顯差異可察。

（3） 高溫顯然可以促進水稻養分吸收量之增加，惟其移行分布之狀態却在二品種之間稍有差異。蓬萊稻在高溫處理下無機養份總吸收量顯有增加，惟此種多吸收之養分却徒使莖葉部分增加而致使養分在穀實中之相對分布率減低。在來稻則與此稍有不同，其因高溫所促進吸收之無機養分能繼續移行於穀實中，故其養分之相對分布比率不但未見低下，反而有增。此種傾向以第一期作較爲明顯。其收穫時之三要素吸收量如下表：

水稻收穫物三要素總吸收量 (mg/pot)

		高溫區			低溫區		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
第一期作	臺中65號	1,140(100)	449(39)	1,287(113)	1,063(100)	465(44)	1,215(114)
	白米粉	1,185(100)	493(42)	1,340(113)	1,081(100)	437(40)	1,234(114)
第二期作	臺中65號	1,311(100)	481(37)	1,434(109)	1,129(100)	424(38)	1,363(121)
	白米粉	1,137(100)	422(37)	1,451(128)	967(100)	422(44)	1,288(133)